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BIBLIOGRAPHY OF STATISTICAL AND METEOROLOGICAL METHODOLOGY IN W--ETC(U)
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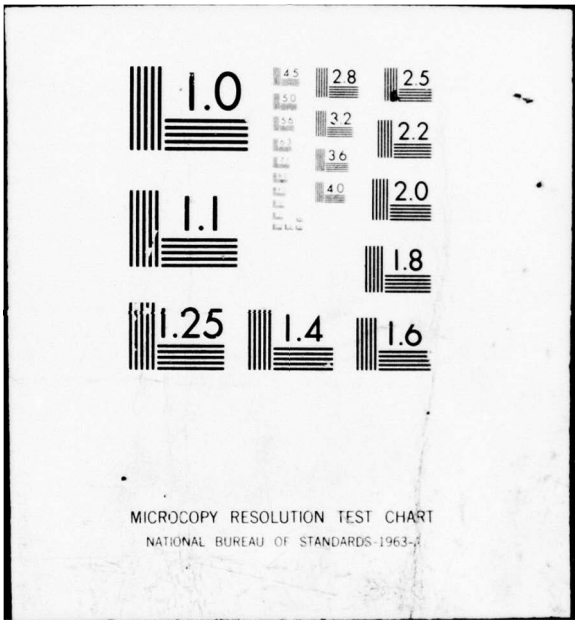
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The Florida State University

Department of Statistics

Tallahassee, Florida 32306

(6) BIBLIOGRAPHY OF STATISTICAL AND METEOROLOGICAL METHODOLOGY IN WEATHER MODIFICATION, II,

by

(10) Morgan A./Hanson, Lawrence E./Barker, and Charles H./Hunter

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Bibliography of Statistical and Meteorological Methodology in Weather Modification, II.

by

Morgan A. Hanson*, Lawrence E. Barker*, and Charles H. Hunter**

Introduction

This collection of abstracts is supplementary to the Bibliography of Statistical and Meterological Methodology in Weather Modification by Morgan A. Hanson, Charles L. Bach, and Edward A. Cooley issued as Florida State University Department of Statistics Report No. M388, September 1976. Motivation for the bibliography arose in association with an Office of Naval Research sponsored contract in the design and analysis of weather experimentation under the direction of Ralph A. Bradley as Principal Investigator.

The first bibliography covered the literature through 1975. This second bibliography is intended to be supplementary to that, containing both a coverage of literature published since that time and the inclusion of a number of papers missed in the first bibliography. The format of this report is the same as before. The bibliography is divided into two sections:

Section 1 - Abstracts of Experimental Literature.

Section 2 - Abstracts of Theoretical Literature and Discussion of Experiments. The abstracts are arranged in alphabetical order within year of publication. The first two digits assigned to the numbering of the publication indicate the year of publication; a following numerical symbol refers to a direct experiment (section 1); a following alphabetical symbol refers to theory or discussion (section 2).

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Each experiment has been coded as follows: (for example, 14-131-51-74 means that a crossover design was used with air generated silver iodide as the seeding agent. Rain gauges were used to measure the results, and the analysis was carried out by t-test).

Experimental Design

11 Two sample using control

12 Two sample using historical records

13 Two sample using estimate of normal rainfall from meteorological parameters

14 Crossover design

15 Single cloud seeding

16 Paired cloud seeding

17 Multiple cloud seeding, with randomly selected unseeded clouds

18 Random seeding of convective bands

19 Periodic seeding

20 Areal pattern recognition

21 Factorial design

22 None given.

Type of Seeding

Prefix 1 - air generated

Prefix 2 - ground generated

Prefix 3 - both air and ground generated

31 Silver iodide

32 Dry ice

33 Water

35 Sodium iodide

36 Sodium chloride

37 Lead aerosols

38 Burning vegetation; urban heat

39 Gasoline engine exhaust; industrial pollution

40 Morpholine, Ethylamine

41 Portland cement

42 Ammonium iodide

43 Ammonium nitrate

44 Urea

45 Phloroglucinol

46 Not specified

Response Variables

51 Rain gauges

52 Stream flows; reservoir runoff

53 Snow measurements

54 Ice counters

55 Particle or drop collectors; Spectrophotometers

56 Radar - cloud census

57 Radar - rainfall/hail/snow

58 Radiosonde

59 Visual; photographs; photogrammetry; crop damage

60 General weather data

61 Cloud texture

62 Hail indicators

Statistical Techniques

71 Regression

72 Correlation

73 z-test

74 t-test

75 Chi-square test

76 F-test

77 C(α) test

78 Single ratio test

79 Double ratio test; Composite ratio test

80 Median ratio test

81 Multivariate analysis

82 Analysis of variance

83 Analysis of covariance

84 Pattern analysis

85 Rank sum test

86 Sign test; Signed rank test

87 Squared rank sum test

88 Rank correlation

89 Kolmogorov-Smirnov test

90 None given.

SECTION I
ABSTRACTS OF EXPERIMENTAL LITERATURE

1968
6813
12-231-52/53-71

Elliot, Robert D. and Lang, William A. (1968)

"Weather Modification in the Southern Sierras"

Journal of the Irrigation and Drainage Division, Proceedings of the American Society of Civil Engineers: 45-59

Experimental Design: Seeding was carried out during the winter season from 1950 to 1965, with the test site located in central California. A control area was chosen to the west of the target area. All storms were seeded. Using historical data, a regression equation was derived for stream runoff in the target area versus stream runoff in the control area. This allowed comparison of the runoff from the target area with the theoretical runoff had seeding not occurred.

Type of Seeding: At various times in the project, 1 to 10% silver iodide in acetone burners. "Pulsed" seeding (burners active for 4 minutes out of every 15) was used from 1951-1956.

Meteorological Conditions: Winter storms

Response Variables: Stream runoff, snow pack water content

Statistical Techniques: Regression

Conclusion: The historical relationship between the target and control areas was changed in such a way as to indicate that seeding had increased streamflow 8.5%. The probability that this result was due to chance has been calculated to be 3%.

1972
7218
11-131-56-90

Simpson, Joanne, Woodley, William L., and White, Robert M. (1972)

"Joint Federal - State Cumulus Seeding Program for Mitigation of 1971 South Florida Drought"

Bulletin of the American Meteorological Society: 334-344

Experimental Design - The target area was Southern Florida, centering on Lake Okeechobee. Randomized days were chosen for seeding. Agricultural concerns and NOAA's hurricane program caused the experiment to be of short duration. Near the end of the experiment, the severity of the drought and accompanying fires caused the abandonment of control clouds.

Type of Seeding: Silver Iodide, released from a DC-6 at 20,000 feet.

Meteorological Conditions: Cumulonimbus clouds were chosen for seeding, in hopes that they would merge into one large cloud.

Response Variables: Radar, space integration of an isohyetal pattern known to be associated with a seeded cloud.

Statistical Techniques: Scattergram

Conclusion: Dynamic Seeding can provide local drought mitigation in Florida, but its real efficacy remains to be established.

1976
761
15-132-55/57-71

Akimov, N.M., Volkov, A.D., and Leskov, B.N. (1976)

"Investigation of Ice Crystals and Dynamics of Crystallization Zone at Modification of Frontal Clouds"

2nd WMO Scientific Conference on Weather Modification. 99-102

Experimental Design: Clouds were randomly chosen for seeding during the winter in the area of Kiev, USSR. The microstructural characteristics of both clouds and precipitation were studied.

Type of Seeding: Solid CO_2, released from an aircraft.

Meteorological Conditions: Winter storms.

Response Variables: Airborne photoelectric counter to measure ice crystal concentration, radar.

Statistical Techniques: Regression analysis, where both maximum and mean ice crystal concentration are treated as dependent variables and time as the independent variable. Crystal shape is considered by regressing crystal width on crystal base.

Conclusions: Ice crystals that form naturally differ in shape from those that form as a result of seeding. The concentration of ice crystals in a cloud climbs rapidly after seeding and then falls off slowly.

762

11-331-59-85/87

Baughman, Robert G., Fuquay, Donald M. and Mielke, Paul W. Jr. (1976)

"Statistical Analyses of a Randomized Lightning Modification Experiment"

JAM, 15, pp. 790-794

Experimental Design: A single target area was used in this experiment in western Montana. The experimental unit was defined as a unit of space and time that limited operations and observations to events that occurred within a specified target area between noon and midnight MST. Once the treatment of an operational day was assigned from a table of random numbers, the next day received the opposite treatment.

Type of Seeding: Both ground-based and airborne Ag I generators were employed.

Meteorological Conditions: The declaration of an operational day depended on a U.S. Weather Bureau forecast of a 30% chance of thunderstorm occurrence in the vicinity of the target area.

Response Variables: Cloud-to-Ground (CG) flash frequency, Intracloud (IC) flash frequency, Total flash frequency (CG + IC + indeterminate flashes per storm), Duration of Lightning Activity (time from first to last flash per storm), Lightning intensity(ratio of total flash frequency to duration of lightning activity). Maximum number of CG, IC, and total flashes for any continuous 5 and 15 minute period within each storm. Return stroke frequency (number of return strokes for discrete and hybrid flashes) Return stroke interval (time interval from first to last return stroke for discrete and hybrid lightning in milliseconds). Continuing current interval of long-continuing current (LCC) flashes.

Statistical Technique: Parametric estimation based on log-normal estimation and two non-parametric tests (2-sample tie-adjusted Wilcoxon and 2-sample tie-adjusted sum-of-squared ranks test).

Conclusion: Results indicate Ag I seeding of mountain thunderstorms reduces the frequency of lightning and alters several lightning characteristics.

763

11-331-57-90

Biondini, Ronald (1976)

"Some Patterns of Inference in the Florida Cumulus Experiment"

2nd WMO Scientific Conference on Weather Modification: 160-164

Experimental Design: An area in South Florida was chosen for experimentation. Randomization was done over days.

Type of Seeding: Ag I, both airborne and from fusees

Meteorological Conditions: Clouds with top temperatures near -10°C.

Response Variables: Radar observations of rainfall and of cloud motion.

Statistical Techniques: Estimation of p.d.f.'s of rainfall, both seeded and nonseeded.

Conclusions: Days were separated into days of greater cloud motion and lesser cloud motion. Motion categories are stronger in their effects than seeding, so it is concluded that weather modification experiments should take cloud motion into account.

765
11-331-51-85

Brown, Keith, Elliot, Robert D., and Thompson, John (1976)

"Seeding Convective Bands in Winter Storms and the Observed Large Scale Effects"

2nd WMO Scientific Conference on Weather Modification: 465-472

Experimental Design: Convective bands embedded in cyclonic storms were the experimental unit, since most winter rain in the experimental area (Santa Barbara, Ca.) is produced by these bands. Bands were randomly chosen for seeding. From 1967-71, seeding was pyrotechnic. From 70-74, seeding was from an aircraft.

Type of Seeding: Ag I

Meteorological Conditions: Winter storms

Response Variables: A dense network of rain gauges

Statistical Technique: Wilcoxon test

Conclusions: It is claimed that the data shows a precipitation increase on the order of 50 to 100% within bands and 25 to 50% for the storm total after seeding. The increased rainfall extended approximately 120 km. downwind from the seeding source, well beyond the target area. Convective bands tend to widen and slow down after seeding.

766
14-231-57/59-90

Changnon, Stanley and Morgan, Griffith (1976)

"Design of Hail Suppression Experiment for the Central United States"

2nd WMO Scientific Conference on Weather Modification: 257-264

Experimental Design: One sampling instrument per square mile is to be placed in an area 100 miles^2 or larger. Raingauges are to be placed every 9 square miles. A 24 hour time period is chosen to be the experimental unit. Seeding will be randomized, with 1/3 seeded at cloud base, 1/3 seeded at mid-cloud, and 1/3 not seeded.

Type of Seeding: Pyrotechnic Ag I

Meteorological Conditions: Clouds that exceed 35 dbz above the freezing level in spring (or 39 dbz above the freezing level in summer - fall) and which have tops growing at 1000 ft/min.

Response Variables: Hailstone size distribution, hail day frequency, storm echo characteristics, and amount of crop - hail loss

Statistical Techniques: Which statistical techniques to be used were not specified.

Conclusions: The experiment was only planned when the paper was presented, and had not been carried out.

767
11-231-55-90

Cooper, William A. and Saunders, Clive P.R. (1976)

"Microphysical Observations in San Juan Storms"

2nd WMO Scientific Conference on Weather Modification: 93-98

Experimental Design: 12 winter storms were chosen at random for study, some seeded and others unseeded. Flights were made through the storm clouds, and data gathered.

Type of Seeding: Ground released Ag I.

Meteorological Conditions: Winter snow storms.

Response Variables: Cloud liquid water content, ice crystal concentration and ice nuclei size.

Statistical Techniques: None

Conclusions: Stable clouds are unseedable, while convective clouds are potentially seedable. The topography of a region, to a large extent, determines the region's suitability for cloud seeding.

768
14-131-51-90

Dennis, A.S., Hirsch, J.H. and Chang, L.P. (1976)

"The Role of Low-Level Convergence in Controlling Convective Rainfall and its Possible Modification by Seeding"

2nd WMO Scientific Conference on Weather Modification: 49-54

Experimental Design: The experiment discussed in the paper was a randomized cross-over design. Seeded days are divided into shower days (without positive vorticity advection) and storm days (with positive vorticity advection). The rainfall on the two types of days was compared.

Type of Seeding: Ag I

Meteorological Conditions: Days were selected for seeding on a basis of moisture and wind conditions.

Response Variables: Rain gauges.

Statistical Techniques: Monte Carlo study of results.

Conclusion: The effect of seeding was positive on shower days. The effect of seeding was inconclusive or negative on storm days.

769
11-236-51-90

Fournier d'Albe, E.M. and Aleman, P.M. (1976)

"A Large Scale Cloud Seeding Experiment in the Rio Nazas Catchment Area, Mexico"

2nd WMO Scientific Conference on Weather Modification: 143-150

Experimental Design: Days for seeding were chosen randomly, independently of weather and conditions. The experiment lasted 76 days, with each day having probability 2/3 of being seeded. The target area was the Rio Nazas Catchment region, with the control region being to the west of this region.

Type of Seeding: Na Cl, dispensed from insecticide dusting machines.

Meteorological Conditions: Warm Clouds, due to time of experiment. Otherwise, varied.

Response Variables: Rain gauges

Statistical Techniques: "Rainfall indices" are calculated by a complicated procedure which is supposed to measure an area's rainfall over a specific period, compared to its overall rainfall. The authors assume a log-normal distribution for rainfall, and compare rainfall indices based on this assumption. The specific type of test performed is not named.

Conclusions: There was "significantly" less rainfall on seeded days. The authors describe the result as "puzzling", since there is no theoretical basis for suspecting seeding decreases rainfall.

7610
11-46-51/57-76/85

Gagin, J. and Neumann, J. (1976)

"The Second Israeli Cloud Seeding Experiment - The Effect of Seeding on Varying Cloud Populations"

2nd WMO Scientific Conference on Weather Modification: 195-204

Experimental Design: The experiment was of the cross-over randomized type. The experiment was carried out in the catchment of Lake Tiberias, Israel. A day that was randomly chosen to be seeded was counted as seeded, even if no seeding occurred for lack of clouds. Experimental unit was 24 hours.

Type of Seeding: Unspecified

Meteorological Conditions: Varied

Response Variables: Rain gauges, radar

Statistical Techniques: F test, Wilcoxon test

Conclusions: The overall increase in rainfall in seeded days over non-seeded days was 1570, and significant at the 0.9% level (F-test). The Wilcoxon test showed a lower level of significance. The greatest increase in rainfall was at the border of the two experimental regions.

7611
15/11-246-57/59-90

Gaivoronski, I.I., Gromova, T.N., Zinin, B.I., Lobodin, T.V., Nikandrov, V.Ja., Toropova, N.V., and Shishkin, N.S. (1976)

"The Experiments on Thunder - Cloud Modification to Reduce Their Electrical Activity"

2nd WMO Scientific Conference on Weather Modification: 421-424

Experimental Design: Anti-Hail "Cloud" type rockets containing 3.1 kg. of ice generating reagent were fired into thunder clouds. A seed/no seed decision was made randomly, with individual thunder clouds as the experimental unit. Northern Moldavia was the experimental site.

Type of Seeding: Rocket borne ice generating reagent, unidentified.

Meteorological Conditions: Thunderstorms

Response Variables: Radar, visual observations, thunderstorm indicators (to count lightning discharges.)

Statistical Techniques: None

Conclusions: The experiment indicated that this type of seeding caused the percentage of cloud to ground lightning discharges to decrease and the percentage of interval lightning discharges to increase. The modification was by an apparent factor of two.

7612
Hicks, James R. and Weinstein, A.I. (1976)

"Glaciation of Supercooled Fog by Compressed Air"

2nd WMO Scientific Conference on Weather Modification: 389-396

Experimental Design: Low pressure steam was used to generate fog in a cold cloud chamber. Compressed air was vented into the chamber from nozzles having diameters of 1.016 mm. and 1.524 mm. at pressures of 1.8, 3.1, 4.1, 5.1 and 6.1 atm.

Type of Seeding: Compressed air

Meteorological Conditions: Artificial supercooled fog at pressures of 1.8 atm. and 4.1 atm.

Response Variables: Ice crystal concentration

Statistical Techniques: None

Conclusions: Supercooled fog can be dispersed by compressed air, but the compressed air system is expensive to operate.

7613
11-46-51-85/72

Howell, Wallace E. (1976)

"On Rainfall Downwind from the Santa Catalina Mountains Seeding Experiments"

2nd WMO Scientific Conference on Weather Modification: 457-464

Experimental Design: The Santa Catalina experiment was carried out near Tucson, Arizona, during the Summer of 1957-1964. Experimental days were selected in pairs with no more than one non-experimental day between them. A 50-50 randomized decision was made to seed the first of the pair, with the second day receiving the opposite treatment. As the title suggests, this paper is a study of rainfall downwind of the target area, conducted apart from the primary experiment.

Type of Seeding: Unspecified

Meteorological Conditions: Summer days that exceeded a specified threshold of precipitable moisture.

Response Variables: Rain gauges

Statistical Techniques: Wilcoxon Test, correlation coefficient.

Conclusions: The author concludes that the possibility of a substantial next day-after-tomorrow increase of 75% was found, but was not significant. The author speculates that seeding initiates or assists some natural process that becomes amplified over time.

7614
11-136-51-82/72

Kapoor, R.K., Krishna, K., Chatterjee, R.M., Murty, A.S.R., Sharma, S.K., and Ramana Murty, Bh.V. (1976)

"An Operational Rain Stimulation Experiment Using Warm Technique Over Rihand Catchment in Northeast India During Summer Monsoons of 1973 and 1974"

2nd WMO Scientific Conference on Weather Modification: 15-20

Experimental Design: A region of area 13,000 km^2 in Northeastern India was chosen for cloud seeding. Two adjacent regions of equal area, one to the west of the target area and one to the east were used as controls. In the first year of the experiment, seeding was conducted on all seedable days when flying was possible. In the second year, every fifth seedable day was left unseeded.

Type of Seeding: Sodium chloride and soapstone in a ratio of 10:1, dispensed from an aircraft.

Meteorological Conditions: If 3 of the following criteria were satisfied, the day was considered seedable.

(i) 3 octa or more of cumulus clouds
(ii) winds steady
(iii) dew point not exceeding 5° at 700mb
(iv) low clouds over the test region

Response Variables: Rain gauges

Statistical Techniques: ANOVA, rainfall correlation coefficents between the target area and the controls.

Conclusion: The data showed that rainfall in the target area increased during the period of seeding upward of 16%. The results were not statistically significant, although the authors do not state what significance level was chosen.

7615

Kapoor, R.K., Paul, S.K., Mukherjee, B.K., Sharma, S.K., and Murty, Bh.V.R. (1976)

"Frequency of Occurrence of Seedable Clouds Based on Measurement of Droplet Spectra"

2nd WMO Scientific Conference on Weather Modification: 7-14

Experimental Design: Droplet size distributions were measured using a spring loaded sampler and magnesium oxide coated slides through the window of an aircraft. The value of static stability was evaluated for all the regions for the days with rich and deficient cloud microstructure. The experiment was carried out in Bombay, Poona, and Rihad, India.

Type of Seeding: None

Meteorological Conditions: Monsoon in Bombay, maritime clouds in Poona, inland on continental clouds at Rihad.

Response Variables: Droplet samples + magnesium oxide film, radiosonde data.

Statistical Techniques: Mann-Whitney test.

Conclusion: Mean static stability did not differ significantly for these regions between days of rich and deficient microstructure.

7616
11-231-51/58-85/87

Keyes, C.G., Jr., and Hackett, F. (1976)

"Comparison of Jemez Analysis Event Results to Seedable Unit Results"

2nd WMO Scientific Conference on Weather Modification: 187-194

Experimental Design: The experiment was carried out in Northern New Mexico. The seedable unit was a 24 hour time period. A randomized seed/no seed decision was made with probability .5 of seeding.

Type of Seeding: Ground based Ag I.

Response Variables: radiosondes, rain gauges.

Meteorological Conditions: Winter storms that had produced .01 inches or more of liquid water were the only storms considered.

Statistical Techniques: Wilcoxon test, squared rank test (both were used, only the Wilcoxon test was discussed).

Conclusions: The data suggests the existence of a "temperature window", outside which seeding has little effect on orographic snow storms.

7617
22-46-57-71/74/76

Klazura, Gerard, and Schroeder, Melvin J. (1976)

"Development of Prediction Variables of Areal Precipitation Characteristics"

2nd WMO Scientific Conference on Weather Modification: 173-180

Experimental Design: Digital radar data collected as part of the Bureau of Reclamations High Plains Cooperative Program were collected and analyzed. Only non-seeded clouds were considered.

Type of Seeding: None

Meteorological Conditions: None given.

Response Variables: Radar readings, rawinsondes.

Statistical Techniques: Least-squares regression - dependent variables are total volume exceeding 10 dBZ reflectivity, maximum reflectivity, and maximum echo height. There are many dependent variables. In testing the hypothesis that the correlation between the dependent and independent variables is zero, both the t and F tests were used.

Conclusions: The correlation coefficient between dependent and independent variables was .64 with only three dependent variables, including precipitable water (surface to 850 mb) and lifted index (100 mb layer, mean mixing ratio, adiabatic.) Adding all variables raised it to .79.

7618
11-136-55-90

Krishna, K., Khemani, L.T., Kanuga, K.K., Mukherjee, B.K., Sharma, S.K., Momin, G.A., and Murty, Bh.V.R (1976)

"An Experimental Study of Medium Scale Diffusion at Cloud Base Level"

2nd WMO Scientific Conference on Weather Modification: 529-537

Experimental Design: A 'seeding agent' was released from a DC 3 aircraft, as in a seeding operation. Immediately before release of the plume, aerosol samples were collected at different levels where samples of the diffusing plume were expected to be collected. After the plume was released, the aircraft flew downward and collected samples. The experiment was repeated for 3 consecutive days between Kedgaon & Parner, India.

Type of Seeding: Na Cl and soaptone, in a ratio of 10:1.

Meteorological Conditions: Clear weather on two of the experimental days, thunderstorms on the third.

Response Variables: Cascade Impactor

Statistical Techniques: None

Conclusions: The diffusion of the plumes did not conform to anticipated patterns. The number of trials in this study is small, and more data is required to draw firm conclusions.

7619
11-131-55-89/75/76/74

Long, Alexis, Crown, Edwin, and Huggins, Arlen (1976)

"Analysis of the Hailfall during 1972-74 in the National Hail Research Experiment"

2nd WMO Scientific Conference on Weather Modification: 265-272

Experimental Design: The experiment was carried out in northeast Colorado. "Hail days" were chosen, and a randomized seed/no seed decision was made, with 50-50 distribution.

Type of Seeding: Ag I bearing rockets, fired vertically from aircraft.

Meteorological Conditions: Storms with reflectivities greater than 35 dBZ.

Response Variables: Hail/rain separators.

Statistical Techniques: Kolmogorov-Smirnov test, chi-square test, F test, t-test.

Conclusions: The data was analyzed separately under the assumption that hailfall has a lognormal or gamma distribution. Although seeded days produced 60-80% less hail, a 90% confidence interval (under both assumed distributions) showed no significant difference. Nothing less extreme than a 50% suppression to 500% enhancement can be excluded.

7620
11-231-?-90

Marwitz, John D. (1976)

"Dynamical Processes in San Juan Storms"

2nd WMO Scientific Conference on Weather Modification: 85-92

Experimental Design: Transport, diffusion, and cloud physics data were gathered over Elk Mountain and the Medicine Bow Mountains in Wyoming, for comparison to similar data gathered in the "statistically designed" Upper Colorado River Cloud Seeding Project.

Type of Seeding: Ground released Ag I.

Meterological Conditions: Cold orographic clouds were chosen for seeding.

Response Variables: "Reliable and rather complete cloud physics instrumentation package", rawinsonde data.

Statistical Techniques: None

Conclusion: The primary role of embedded convection is to transport cold, dense air upward, allowing warm moist air to be advected, thereby invigorating convection. Thus, the chances of successful seeding are increased when embedded convection is present.

7621
12-131-57/59-90

Mather, G.K., Cooper, L.W., and Treddenick, D.S. (1976)

"The Nelspruit Hail Suppression Program"

2nd WMO Scientific Conference on Weather Modification

Experimental Design: Seeding was carried out whenever storms appeared near Nelspruit, Republic of South Africa. Historical data for the same area was used as a control.

Type of Seeding: Seeding was of the aerial type, with silver iodide as the seeding material

Meteorological Conditions: Cloud top heights exceeding 12 km., maximum reflectivities greater than 45 dbz.

Response Variables: Radar, crop damage data.

Statistical Techniques: Construction of histograms.

Conclusions: As this was not a designed experiment, conclusions are tentative. Hailfall has lessened, according to the paper, in seeded years, by 24%. Compared to historical data and assuming hailfall has a β distribution, the difference is significant at the .025 level.

7622
12-131-59-89/85/86

Miller, J.R., Dennis, A.S., Schwaller, R.L., and Wang, S.L. (1976)

"Evaluation of a State-Wide Operational Weather Modification Program Using Crop-Hail Insurance Data"

2nd WMO Scientific Conference on Weather Modification: 287-294

Experimental Design: Seeding was carried out over certain South Dakota counties. For economic reasons, all storms were seeded, so the experiment was not randomized. Hail damage in the target counties was compared to that in surrounding counties. Taking another approach, hail damage state-wide during the years in which the seeding was carried out was compared to historical state-wide data.

Type of Seeding: Ag I

Meteorological Conditions: Varied

Response Variables: Crop/loss from hail fall.

Statistical Techniques: Construction of histograms. To compare seeded counties with non-seeded counties, the Kolmogorov-Smirov test and the Wilcoxon tests were used. To compare seeded years with non-seeded years, the sign test was used.

Conclusions: Seeded counties had less hail damage than non-seeded, and seeded years had less than non-seeded. However, in neither case was the difference significant. A 7% advantage in rainfall was observed in seeded counties over non-seeded.

7623
22-31-AgI-89/87/

Mulvey, Gerald J. and Grant, Lewis O. (1976)

"A Physical Mechanism of Extra Area Effects from the Climax Orographic Cold Cloud Seeding Experiment"

2nd WMO Scientific Conference on Weather Modification: 473-479

It is hypothesized that the physical mechanism by which ice crystals are transported and interact with clouds downwind of a seeding project involves a combination of downwind wave motion, particle sedimentation, mixing associated with downwind convective cells, and a subsequent change in cloud microphysics. To test this hypothesis, freshly fallen snow 177-200 km. downwind of the Climax seeding project was collected and analyzed by flameless atomic absorption for trace silver.

Type of Seeding: Ag I

Meteorological Conditions: Orographic cold clouds.

Response Variables: Tests for trace Ag

Statistical Techniques: Kolmogorov-Smirnov test, R^{th} power rank test, maximum likelihood ratio test for a 3-parameter Kappa distribution.

Conclusions: The difference in seeded and non-seeded sample sets is significant at the 0.59 level. While more documentation is needed, the observations support the hypothesized mechanisms of transport and microphysical processes.

7624
11-237-62-85/89

Núñez, J.M. and Spreafichi, M.I. (1976)

"An Outline fo the National Hail Suppression Program in Argentina"

2nd WMO Scientific Conference on Weather Modification: 229-236

Experimental Design: An agricultural region of the Argentinian Province of Mendoza was chosen for the experiment. Control regions were chosen surrounding the test area on the North, South, and West. Seeding was randomized over days in which hail was predicted.

Type of Seeding: Pyrotechnic PbI_2

Meteorological Conditions: Days from October to March in which hail is forecast.

Response Variables: Radar and visual observation of hailfall, the amount of damage done by the hail.

Statistical Techniques: Wilcoxon and Kolmogorov-Smirnov tests.

Conclusion: The experiment was still in progress at the time the paper was presented, so the results are naturally inconclusive.

7625
11-?-53-71

Plooster, M.N (1976)

"Orographic Snowfall Prediction with a Numerical Model"

2nd WMO Scientific Conference on Weather Modification: 131-134

Experimental Design: Snowstorms over the San Juan mountains in Colorado were randomly chosen for seeding. Continuous precipitation data was recorded by a network of gauges.

Type of Seeding: Unspecified

Meteorological Conditions: Seeding was carried out when snow was forecast or falling.

Response Variables: Snow gauges, rawinsondes, microphysical properties of clouds.

Statistical Techniques: Regression.

Conclusion: A model for predicting orographic snowfall was devised. In the field studies of the experiment, the coefficient of correlation between model and observation is 0.862. The model uses both meteorological conditions and geographic conditions as independent variables.

7626

Sand, W.R., Halvorson, J.L., and Kyle, T.G. (1976)

"Turbulence Measurements Inside Thunderstorms Used to Determine Diffusion Characteristics for Cloud Seeding"

2nd WMO Scientific Conference on Weather Modification: 539-545

Experimental Design: An armored T-28 aircraft was used to probe the interior of thunderstorms in northeast Colorado for a period of several years. The turbulent energy dissipation rate was derived from fluctuations in true air speed. Seeding was carried out both at cloud base and at cloud top, to compare diffusion.

Type of Seeding: Unspecified

Meteorological Conditions: Thunderstorms

Response Variables: Air speed of particles of seeding material.

Statistical Techniques: None

Conclusions: The seeded volume per unit time is $1.5 \times 10^7 m^3$/sec. for cloud based seeding, and $7.1 \times 10^6 m^3$/sec. for cloud top seeding. This compares to a normal air flow through the cloud of $10^9 m^3$/sec. Then only about 1.5% of the air passing through a thunderstorm is actually being seeded using the common cloud base seeding techniques, and 0.7% using the cloud top technique.

7627
11-231-51-90

Sax, Robert I. (1976)

"Microphysical Response of Florida Cumuli to Ag I Seeding"

2nd WMO Scientific Conference on Weather Modification: 109-116

Experimental Design: Randomized block design, with days being the blocks. Cloud suitability was based on visual appearance, vertical velocity, liquid water content and ice particle concentration of clouds. Floating target area.

Type of Seeding: Ag I, pyrotechnics.

Meteorological Conditions: Supercooled cumulus towers were chosen for seeding.

Response Variables: Rain gauges within the target areas. A DC-6 air craft equipped with foil impactor, particle spectrometer, lyman-alpha water probe, etc. was used for in-cloud measurements.

Conclusions: Seeding can increase the quantity of ice in a cumulus cloud if the cloud is seeded while it is still growing. However, seeding towers of insufficient width hastens their demise.

7628
11-46-59-85

Vardiman, Larry, and Hartzell, Curtis (1976)

"Seeding Effects on Ice Crystal Characteristics in the Colorado River Basin Pilot Project"

2nd WMO Scientific Conference on Weather Modification: 103-108

Experimental Design: Winter storms were divided into 3 hour blocks. Data from ice nucleus counters upwind from the target area were used to determine if any particular blocks should or should not be needed.

Type of Seeding: Not given

Meteorological Conditions: Winter orographic clouds. Since the seed/no seed decision was based on ice nucleus counter data, the seed set may differ meteorologically from the no-seed set.

Response Variables: Photographic ice crystal replicator.

Statistical Techniques: Wilcoxon two-sample test.

Conclusions: Seeding increases crystal concentration and precipitation.

7629
15-133/139-57/59-90

Vulfson, N.I., Gaivoronski, I.I., Zatsepina, L.P., Zinin, B.I., Levin, L.M., and Seregin, Yu. A. (1976)

"Destruction of Convective Clouds by Dynamic Method"

2nd WMO Scientific Conference on Weather Modification: 413-420

Experimental Design: Downdrafts were created in cumulus clouds by the following methods: (a) release of a certain mass of roughly dispersive powder of water spray (b) horizonal flight of an airplane (c) gas jet or (d) charge explosions of antihail shells without the ice-forming reagent. This process was applied to several hundred clouds. The results were observed visually or with radar. The experiment was considered successful if the cloud dispersed 25% or more.

Type of Seeding: As above

Meteorological Conditions: Clouds developing due to thermal convection or under the influence of fronts.

Response Variables: Radar, visual observation.

Statistical Techniques: None

Conclusions: The radar echo lifetime of modified clouds was shortened by a factor of 1.5. The experiment was less successful on clouds of frontal origin.

7630
11-131-57/55-76/74

Wisniewski, Joe (1976)

"Variability of Rainwater Silver Concentration in South Florida"

Experimental Design: The study reported in this paper was a subprogram of the Florida Area Cumulus Experiment. Clouds in the test area were randomly chosen for study, some seeded and others non-seeded. A Queenair aircraft equipped with a rainwater collection scoop, a continuous aerosol collector, and other meteorological instruments was flown through the cloud repeatedly, with the goal of sampling from a cloud from its beginning to its dissipation. The samples were immediately frozen, to prevent absorbtion of silver, and later analyzed by means of a Perkins-Elmer 403 flameless atomic absorption spectrophotometer.

Type of Seeding: Ag I

Meteorological Conditions: Interiors of cumulus clouds.

Response Variables: Radar, tests for trace Ag

Statistical Techniques: F-test, t-test

Conclusions: The mean seeded silver concentrations and their variances were significantly ($P\alpha$ = .038 for t-test, .005 for F-test) larger than the non-seeded samples. There seems to be no persistence of silver for a day following an initial seed day.

7631
11-331-57/51-74/85/76/83

Woodley, W.L., Simpson, Joanne, Biondini, Ronald, and Sambataro, George (1976)

"On NOAA's Florida Area Cumulus Experiment - Main Rainfall Results 1970 - 1975"

2nd WMO Scientific Conference on Weather Modification: 151-158

Experimental Design: A fixed target area was chosen, and seeding was randomized over days.

Type of Seeding: Ag I, from ground launched flares and aircraft.

Meteorological Conditions: Hard, vigorous clouds with top temperatures near -10° C.

Response Variables: Radar, adjusted by rain gauges.

Statistical Techniques: T test, applied to raw data and transformed (4th root) data, Wilcoxon test, F test, Welch test, analysis of covariance.

Conclusions: Echo motion is a significant covariate in accounting for rain variability.
Tentative conclusions are:
(1) positive significant treatment effect.
(2) Seeding increasing variance significantly.

1977
771
I--131-57-83

Woodley, William L., Simpson, Joanne, Biondini, Ronald and Berkeley, Joyce, 1977

"Rainfall Results, 1970-75: Florida Area Cumulus Experiment"

Science, 195, pp 735-742

Experimental Design: In FACE, a random experimental design is used which involves randomization of days over a single target area into seed and noseed days over a single target area into seed and noseed days, with noseed days as the control. The experiment is carried out in a 1.3×10^4 square kilometer area in south Florida.

Type of Seeding: Aircraft dropping silver iodide flares.

Meteorological Conditions: Summertime cumulus.

Response Variables: 10-centimeter radar

Statistical Analyses: Covariate analyses

Conclusions: Analysis without the benefit of data stratification and appropriate covariate of the 48 random experimentation days obtained through 1975 provided no evidence that dynamic seeding appreciably altered the rainfall over the fixed target area. Partitioning of the experimental days was more informative. Discussion of covariates (echo motion) and meteorological predictors is given.

SECTION 2
ABSTRACTS OF THEORETICAL LITERATURE AND DISCUSSION OF EXPERIMENTS

1960
60C

Elliot, Robert D. (1960)

"Seeding of West Coast Winter Storms"

Journal of the Irrigation and Drainage Division, Proceedings of the American Society of Civil Engineers: 45-59

Here we have a detailed consideration of the mechanics of a winter cloud seeding operation. The structure of a manually operated silver iodide generator is discussed, along with the problems of using such a system in seeding winter storms. Similar consideration is given to radio controlled generators.

Studies of the dispersal of silver iodide smoke, using zinc and cadmium sulfide fluorescent particles, are discussed. Schematic diagrams for the possible travel of nucleating smoke after release from a ground based generator are given.

Consideration is given to such topics as atmospheric motion and natural nuclei and their effect upon weather modification.

For the evaluation of cloud seeding, it is recommended that a control area near the target area be chosen, and a regression equation derived. It will then be possible to "hindcast" what the rainfall in the target area would have been had there been no seeding.

It is noted that 10-15% increase in snowfall are considered economically beneficial, over and above the cost of seeding. This is the degree of enhancement associated with seeding winter storms, making such operators economically feasible.

60D

Howell, Wallace E. (1960)

"Seeding of Clouds in Tropical Climates"

Journal of the Irrigation and Drainage Division, Proceedings of the American Society of Civil Engineers: 349-371

A synopsis of major tropical cloud seeding experiments (1948-1958) is given, including commercial operations. It is noted that in most of these projects, including the possibly biased commercial ones, the reported percentage increase of rainfall is near 25%.

The results of warm cloud seeding agree with current theories of precipitation formation in tropical clouds, but the results for cold-cloud seeding do not. Consequently, a new model of convective cloud fields is proposed. This model, which describes cloud growth in terms of the accumulation of precipitation particles, is in agreement with observation.

1964
64A

Schleusener, Richard A. (1964)

"Weather Modification"

Journal of the Hydraulics Division, Proceedings of the American Society of Civil Engineers: 57-95

An overview of research activities in weather modification (1959-1963) is given, with summaries of the methods and results of selected experiments. Citing these experiments as support, it is claimed that the enhancement of precipitation by seeding has, under certain conditions, been established. It is recognized that seeding, under certain conditions, may result in a decrease of rainfall.

At the time of this article, the "carry-over" effect of seeding had just been discovered. Accordingly, it is suggested that weather modification projects begin with concentrated seeding, to enhance this overall effectiveness.

1970
70D

Braham, Roscoe R., Jr., and John A. Flueck, (1970)

"Some Results of the Whitelop Experiment"

2nd National Conference on Weather Modification: 176-179

The aim of this contribution was to provide an up-to-date (1970) summary of the authors continuing study of data measured on Project Whitetop.

Topics discussed are the "over-all" or "net" effect, effects in portioned data, uncontrolled factors, and long range seeding effects.

Two general conclusions are presented plus four other results are discussed in view of the insight gained from concurrent study of precipitation mechanisms.

70E

Chagnon, Stanley A., Jr., (1970)

"Design Factors of a Hail Suppression Experiment in Illinois"

2nd National Conference on Weather Modification: 150-155

The author discusses what would be the best, or optimum, design for a meaningful hail suppression experiment in Illinois. Design factors he considers are: statistical design, the geographical location of the study area, size of the area, shape of the area, type of surface hail

data to be collected, density of point observations, collection of allied weather data, seeding considerations, hail forecasting methods, monitoring of hail aloft, duration of the project, and methods for evaluating the results.

Certain of the design results are applicable to experimentation in other hail climates, and an application of the Illinois results to the design of hail suppression in Italy is described in this paper.

70F

Smith, E.J., (1970)

"Cloud Seeding with Pyrotechnics in Australia"

2nd National Conference on Weather Modification: 186-189

This paper describes experiments in which pyrotechnic cartridges were fired into large cumulus clouds in Australia. The objective was to make preliminary observations of events following seeding. Statistical evaluation was not attempted at this stage.

Results suggested that meteorological conditions in this part of Australia are suitable for cloud seeding with pyrotechnics and further investigations were justified.

1971
71G

Lovasich, Jeanne L., Neyman, Jerzy, Scott, Elizabeth, and Wells, Marcia A.

"Further Studies of the Whitetop Cloud-Seeding Experiment"

Proceedings of the National Academy of Sciences, Vol. 68, No. 1, pp 147-151, Jan. 1971

The Whitetop experiment covered five summers, with the target area being near West Plains, Missouri. The test area was divided into concentric circles about the seeding site, and rainfall within the circles were compared. All areas showed large decreases in rainfall, with significant probabilities of less than .03.

This study stratifies the data based on two categories, wind direction, and air mass vs. frontal. For west wind and frontal days, no significant effects were found. For east wind and air-mass days, significant decreases in rainfall (up to 75%) were recorded up to 180 miles away.

By taking only wet days into account, the apparent negative effect becomes only mildly significant.

1972
72L

Battan, Louis J. (1972)

"Cloud Seeding and Rainmaking"

Statistics: A Guide to the Unknown: 354-361, Holden-Day Inc., San Francisco.

A brief history of the development of cloud seeding is given. The problems that accompany the design and interpretation of a weather modification experiment are discussed.

Graphs of August rainfall in inches for two large cities versus years (1930-1968) are displayed, making obvious the difficulties in determining whether rainfall variation is due to seeding or natural variation. The use of regression to overcome these difficulties is considered, while noting that regression lines for different periods of time may differ, limiting the usefulness of this method. The use of the crossover design is also discussed.

It is concluded that the time effectiveness of weather modification techniques is as yet unknown, and further experimentation is needed.

72M

Droessler, Earl G. (1972)

"Weather Modification, Review and Perspective"

Bulletin of the American Meteorological Society: 345-348

The author advocates weather modification procedures (which he prefers to call "weather management") being carried out on a regular and large scale basis. In the view of the author, the effectiveness of such procedures as precipitation enhancement and fog dispersal have been established, and resources should not be diverted to further experimentation. National and international aspects of such a program are considered.

72N

Julian, Paul R. and Murphy, Allan H. (1972)

"Probability and Statistics in Meteorology: A Review of Some Recent Developments"

Bulletin of the American Meteorological Society: 957-965

Developments in six areas of statistical meteorology are described. The areas are:

(1) Stochastic - dynamic prediction,
(2) assimilation of observed data,
(3) time-series analysis,
(4) statistical weather forecasting,
(5) probability forecasting, and
(6) precipitation modification statistics.

Special consideration is given to the latter, and the problems inherent in the design of weather modification experiments are discussed.

720

Miller, Robert G. (1972)

"The Probability of Rain"

Statistics: A guide to the unknown: 372-384, Holden-Day Inc., San Francisco

A general description of the use of discriminant analysis in weather forecasting is given, and a simplified example is worked out. More complicated techniques than the ones used are mentioned, including those that allow for qualitative (as well as quantitative) predictors and those that systematically handle missing data.

1973
73C

Battan, Louis J. (1973)

"Survey of Weather Modification in the Soviet Union: 1973"

Bulletin of the American Meteorological Society: 1019-1030

A review of abstracts of articles dealing with Soviet weather modification activities is given. The major portion of Soviet efforts are devoted to hail experimentation, although effort is also directed toward fog dispersal, lightning suppression, and other related efforts. Plans to carry out weather modification procedures over large weather systems were apparently never carried out.

73D

Bujkov, M. V. and Korsienko, E. E. (1973)

"Methods of Estimating Physical and Economic Effectiveness of Weather

WMO/IAMP Scientific Conference on Weather Modification: 421-430

Consideration is given to the cost of having a sample size large enough to have specified values of α and β for specified tests when applied to weather modification experiments. The techniques of game theory are applied to the problem of balancing gain (information) and loss (expense of the experiment).

73E

Changnon, Stanley A., Jr. (1973)

"A Review of Methods to Evaluate Precipitation Modification in North America"

WMO/IAMP Scientific Conference on Weather Modification: 397-422

A brief history of the design of weather modification experiments is given. Various designs (eg. target-control, cross-over randomized, one area continuous) are compared, and advantages and disadvantages of each one discussed. Methods of evaluation of a weather modification experiment, such as radar, raingages, stream runoff, etc., are likewise compared. Attention is given to the cost of each method.

It is concluded that the most serious obstacles to detecting seeding effects are natural variablilty and the high cost of experimentation.

73F

Chagnon, Stanley A., Jr. (1973)

"Weather Modification in 1972: Up or Down?

Bulletin of the American Meteorological Society: 642-646

Here we have a study of the major weather modification projects, both operations and research, carried out in 1972. Major findings of the year are discussed, along with problems and controversies. It is noted that concerns about the overall effect of weather modification on the environment first became prominent in 1972.

73G

Derjaguin, B. V., Grigorenko, I. N., Erslov, V. A., Zolotarev, I. A., Kurgin, Yu. S., Leonov, L. F., Maliksov, B. A., Prokhorov, P. S., Fedoseev, V. A., Shaglij, E. I., Shustov, V. A. and Kudritsij, S. B. (1973)

"Problems of Radiation Fog Prevention"

WMO/IAMP Scientific Conference on Weather Modification: 29-33

The methods of radiation fog prevention which are based on heat transfer or utilization of hygroscopic substances are expensive to put into practice. An alternative method, artifically reducing the condensation activity of nuclei by coating them with monolayers to reduce adsorption rate, is discussed here. The effect of adsorption of cetyl alcohol vapor on the condensation of water drops is considered.

73H

Haas, J. Eugene (1973)

"Social Aspects of Weather Modification"

Bulletin of the American Meteorological Society, 647-657

A study is made of public reaction to weather modification procedures, both pro and con. Public reaction to unusual weather occurrences that coincide with weather modification procedings - such as flash flooding or drought - is considered. The lack of public opposition to weather modification is attributed in part to the lack of a forum for effectively expressing disapproval.

73I

Hershfield, David M. (1973)

"On the Probability of Extreme Rainfall Events"

Bulletin of the American Meteorological Society: 1013-1018

Several distributions (such as double exponential, log normal, and gamma) are considered as possible models for outlines in meteorological data. Elementary probabilistic considerations are applied to determine the relationship between risk of occurrence of extreme events (e.g. floods) and their return period.

73J

Huff, F. A. and Changon, S. A., Jr. (1973)

"Precipitation Modification by Major Urban Areas"

Bulletin of the American Meteorological Societ : 1220-1232

Historical records from eight urban areas of varying size and climate were studied for indications of inadvertent weather modification. It was found that warm seasonal rainfall had increased 9-17% from 1955-1970, with the increase arising from enhancement (as opposed to initiation) of moderate to heavy rain days. It is suggested that this enhancement is related to city size and industrial nuclei generation. Evidence is found that the mechanisms of inadvertent weather modification in wet and dry years differ.

73K

Jiasto, James E. (1973)

"Seeding Requirement for Rapid Glaciation or Stimulation of a Mixed Phase Cloud"

WMO/IAMP Scientific Conference on Weather Modification: 169-178

In 1968 the author found an equation which can be used to estimate the number of nuclei necessary to rapidly glaciate a supercooled cloud. In this paper, the estimate is refined to allow for particular crystal types and for several pressure levels. Implications of the estimate for cloud modification are discussed.

73L

Kachurin, L. G., Artemyeva, N. D., Kartsivadze, A. I., Stoganov, S. and Tekle, M. (1973)

"Simulation of the Natural Process of Hail Formation and its Transformation Under the Influence of Artificial Crystallization"

WMO/IAMP Scientific Conference on Weather Modification: 231-237

A system of 19 non-linear first-order differential equations and 29 algebraic equations to model convection crystalization, etc. within hail cells was derived and solved. According to this model, hail growth is extremely sensitive to temperature and wind. The model shows that competition for moisture between hail embryoes and artificially formed ice crystals does not take place, so the effect of hail suppression lies elsewhere, in the reduction of the layer of intensive crystalli zation, for example.

73M

Kacharin, L.G., Medaliev, H.H. and Karmov, N.I. (1973)

"On the Possibility of Thunderstorm Suppression by Changing the Non-Equilibrium Crystallization Potentials of Cloud Water"

WMO/IAMP Scientific Conference on Weather Modification: 275-281

Characteristics of lightning radiation fields are studied. By means of these fields, the development of a thunderstorm may be broken down into three segments, distinguished by spectral distributions of radiation field density, in terms of duration and frequency of pulse parcel radiation. It is found that it is easier to intensify a storm than reduce it.

73N

Lansford, Henry (1973)

"Weather Modification: the Public Will Decide"

Bulletin of the American Meteorological Society: 658-660

This paper is a study of the political impact of weather modification. By drawing historical analogies with the SST, the author concludes that the continuation of weather modification procedures is contingent on public acceptance. The author makes suggestions on how practicing weather modifiers can make their operations more palatable to the general public.

730

Muchnik, V.M. and Djaihak, V.A. (1973)

"Some Questions of Thunderstorm Lightning Control"

WMO/IAMP Scientific Conference on Weather Modification: 283-288

Consideration is given to various theories concerning the formation of thunder storms, and discrepencies between these theories and observed facts are noted. Historical records of thunderstorms are examined to attempt to find a link between atmospheric pollution and the thunderstorms. No such link is found.

73P

Poc. M. M., and Roulleau, M. (1973)

"Preparation and Properties of 'Pure' Silver Iodide Aerosol"

WMO/IAMP Scientific Conference on Weather Modification: 485-498

This paper is a discussion of the preparation of Silver Iodide that is relatively free from impurities. Such impurities can intefere with its properties as an ice nucleant. The size of the particles of Silver Iodide aerosols are also discussed. The paper includes many diagrams explaining the workings of equipment used in the manufacture of Ag I.

73Q

Scott, William D. (1973)

"The Acquisition of Information During Attempts at Weather Modification"

WMO/IAMP Scientific Conference on Weather Modification: 353-362

A series of suggestions for the design of weather modification experiments is made, along with comments on measuring and instrumentation. Problems of trying to issure that ones sample contains sufficient information are discussed.

73R

Stalevick, D. D., Uchevatkina, T. S., and Shishkin, N. S. (1973)

"Theoretical Research into Artificial Stimulation of Precipitation for Fighting Forest Fires"

WMO/IAMP Scientific Conference on Weather Modification: 91-94

Two questions are considered - what is the optimal expenditure of seeding agent, and at what distance should clouds be seeded to use artificial precipitation as a means of extinguishing forest fires. Computer simulations were used to produce nomograms of precipitation vs. amount of seeding agent and precipitation falling on fire vs. distance from point of seeding.

73S

Stout, Glen E. (1973)

"Economic Aspects of Precipitation Augmentation Over the Great Lakes"

WMO/IAMP Scientific Conference on Weather Modification: 431-447

This paper assumes that it is technically feasible to increase rainfall over the Great Lakes by from 10 to 30%, thereby recycling evaporated water. The consequences of doing so are the topic of the paper. Among items considered are hydrologic factors, economic benefits and disadvantages of increased water level in the lakes, and the influence on outflowing rivers. Historical data is used in estimating the dollar gain of increased water levels (from shipping, hydroelectric power, etc.) and the dollar loss in terms of shore property. Based on cost estimates of professional seeders, the author concludes such a project is economically worthwhile.

73T

Takahashi, Yoshihiko (1973)

"On the Efficient Size and Concentration of Spray Drops for Stimulating Warm Clouds"

WMO/IAMP Scientific Conference on Weather Modification: 61-80

The critical size at which cloud droplets begin rapid growth by mutual collision due to turbulence is derived, along with a set of differential equations for the transfer of water from small to large drops as collisions occur. The applicability of the above to cloud seeding is considered, and an approximately optimal size for spray drops to produce dense drizzle is derived.

73U

Warren J. (1973)

"Rain Enhancement - A Review"

WMO/IAMP Scientific Conference on Weather Modification: 43-50

Here we have an evaluation of the problems involved in designing a cloud seeding experiment. Problems given special consideration include the large number of uncontrolable meteorological variables involved and the variability of pre-seeded clouds. Historical experiments which have (and some which have not) had good designs and their results are discussed.

1974
74Z

Ackerman, William C. and Changon, Stanley A., Jr. (1974)

"The New Weather Modification Law for Illinois"

Bulletin of the American Meteorological Society: 745-750

This article is a study of the form of and possible effects of Illinois "permissive-control" type of weather modification law. The law was intended to be a "model law" of state weather modification legislation. The provisions of the law are discussed in detail.

74AA

Charak, Mason T. and DiGiulian, Mary T. (1974)

"A Review of Federal Legislation on Weather Modification"

Bulletin of the American Meteorological Society: 755-757

A study is made of past federal legislation dealing with weather modification, and possible trends are noted. Although there has been little such legislation, more is expected in the future, and these new laws and expected to be more comprehensive than current laws.

74BB

DiGiulian, Mary T. and Charak, Mason T. (1974)

"Survey of State Statutes on Weather Modification"

Bulletin of the American Meteorological Society: 751-754

All U.S. state laws dealing with weather modification in effect in 1973 are surveyed. Most such state laws concern the establishment of Weather Modification Commissions, operator liscence requirements, and operator financial responsibility for results of modification activities. The laws of each state are given in tabular form.

1975
75B

Changnon, Staley A., Jr. (1975)

"The Paradox of Planned Weather Modification"

Bulletin of the American Meteorological Society: 27-37

It is noted that between 1967 and 1975, major advances in weather modification technology came to pass. Despite this development and despite an overall increase in federal support for R & D, support for weather modification decreased. This decrease is attributed to environmental concerns and the use of weather modification by the military in S.E. Asia, among other causes. Future occurrences that could promote or retard the growth of weather modification are discussed.

75C

Droessler, E. G. (1975)

"Weather Modification - Some Proposals for Action"

Bulletin of the American Meteorological Society: 676-678

The author outlines his proposals for a rational weather modification program. His chief proposals are:

1) Establish a National Commission on Weather Modification, which will "study and work through a common sense approach to federal... regulation."
2) Bring the Department of Agriculture into weather modification activities associated with agriculture and
3) Actively support four or five large sound field programs in weather modification.

1976
76A

Alusa, Alexander L. (1976)

"The Occurence and Nature of Hailstones in Kericho, Kenya"

2nd WMO Scientific Conference on Weather Modification: 249-256

A study of historical hail data collected in and about Kenya was carried out. Meteorological parameters associated with hail occurrence were emphasized, with the goal of improving hail forecasting techniques. The author stressed the importance of understanding the mechanisms that give rise to hail storms before hail suppression work begins.

76B

Anav, A. and members of Hail and Thunderstorms Group of IFA - CNR, Rome, Italy (1976)

"Research Project on Anti-Hail Experiments"

2nd WMO Scientific Conference on Weather Modification: 237-239

The authors criticize various hail suppression experiments carried out throughout Europe. Some are criticized on theoretical grounds as ineffective and others on economic grounds as impractical. An alternative experiment is proposed by the authors, which they claim avoids the difficulties of the others.

76C

Atlas, David (1976)

"The Present and Future of Hail Suppression"

2nd WMO Scientific Conference on Weather Modification: 207-216

A brief history of hail suppression experiments and their results is given. Reasons are given for inconclusive results, and problems for experiments arising from unconsious bias are discussed.

76D

Barge, B.L. and Bergwall, F. (1976)

"Fire Scale Structure of Convective Storms Associated with Hail Production"

2nd WMO Scientific Conference on Weather Modification: 341-348

A one dimensional hail category model was given, and its ability to simulate the hail process in cumulonimbus clouds was demonstrated. Only naturally occuring unseeded clouds were considered, so the degree to which the model can simulate modified hail remains unknown.

76E

Bark, L. Dean and Henz, John F. (1976)

"A Survey of the Radar Echo Population Over the Western Kansas High Plains"

2nd WMO Scientific Conference on Weather Modification: 55-62

The survey consisted of analyzing meteorological data gathered by the National Weather Service for the western half of Kansas, April through September, 1972 through 1974. It was concluded that characteristics of convective echoes, other than the number of echoes, remain comparable from year to year.

76F

Braham, R.R., Jr. (1976)

"Modification of Clouds and Weather by a Large Metropolitan Area"

2nd WMO Scientific Conference on Weather Modification: 435-442

The St. Louis, Missouri metropolitan area was chosen for a study of the effects of a large urban - industrial area on weather. Urban effects on cloud nuclei, cloud microstructure, and visibility are discussed. The urban heat island is considered, with its effect on humidity, wind, and cloud formation. Urban effects on precipitation are poorly understood, and various hypotheses as to these effects are given.

76G

Brier, Glenn and Meltesen, Gayle T. (1976)

"The Use of Transformations to Minimize the Influence of Extreme Rainfall Values in Correlation Analysis"

2nd WMO Scientific Conference on Weather Modification: 181-186

Rainfall data was collected from northeast Colorado from 1959 through 1968. Random samples were chosen from this data for conducting a Monte Carlo study of transformations of data. The transformations studied were:
$y = (1+x)^p$, $p = 2, 1/2, 1/4, 1/8, 1/16$, and $y = \ln(1+x)$.
A slight increase in normality appears with the transformation $y = (1+x)^2$. All other transformations yield results comparable to untransformed data. The authors attribute this to the large number of zeros included in the rainfall data.

76I

Dabiri, A.E., Nemat, G., and Warburton, J.A. (1976)

"Design Considerations of a Winter Orographic Cloud-Seeding Program - Alborz Mountains, Iran"

2nd WMO Scientific Conference on Weather Modification: 35-40

The design of a yet-to-be executed experiment was discussed in detail. The experiment may be a two target, randomized cross-over design, a choice of two areas for target control, or a single target area for seed-no seed randomization. Advantages of each design were given. Response variables are to include precipitation amount and duration. Radar and precipitation gauges will be used to record data. Silver iodide from ground based generators will be used for cloud seeding.

76J

Downie, Currie S. and Dirks, Richard A. (1976)

"National Science Foundation Weather Modification Program"

2nd WMO Scientific Conference on Weather Modification: 557-562

An overview of weather modification projects supported by the National Science Foundation is given. These include:

(i) National Hail Research Experiment - a randomized seeding experiment to determine the potential for modifying hail and rainfall by seeding.

(ii) A study on lightning protection.

(iii) Attempts to better describe the characteristics of severe thunderstorm gust fronts and to develop warning systems for the presence of wind shear.

(iv) studies of the effect of urbanization and industrialization on weather and climate and

(v) A study of the influence of widespread irrigation on the climate of the Great Plains.

Other studies are mentioned as being under way or as topics for which investigation exists.

76K

Eccles, P.J. (1976)

"Cumulative Estimates of Hail Mass and Kinetic Energy from Dual-Wavelength Radar Measurement"

2nd WMO Scientific Conference on Weather Modification: 273-280

An expression is derived by means of which it is possible to give precise estimates of median hail diameter, hail mass, and hail energy by use of dual-wavelength radar. The advantages of this procedure over ground networks and damage estimates in hail suppression experiments are discussed.

76L

English, Marianne and Wong, Raymond K.W. (1976)

"Simple Numerical Cloud Models as Potential Tools in Evaluating Hail Suppression Techniques"

2nd WMO Scientific Conference on Weather Modification: 357-362

A number of models that predict maximum hail size from easily observable quantities (such as temperature and maximum updraft speed) are discussed. Hail sizes are divided into categories in terms of familiar objects - e.g. shot, pea, grape, etc. Correlation coefficients and regression lines for the various models one computed. The correlations are generally high, suggesting that these models can find application in hail suppression experiments.

76M

Federer, Bruno and Waldvogel, Albert (1976)

"Hail Growth Zones in Different Storm Types"

2nd WMO Scientific Conference on Weather Modification: 303-311

A detailed discussion of the physics of hail formation is given. The potential significance of this with respect to hail suppression is considered. Examples of hailstones collected from specific storms are given, and these are compared with the theoretical expected type of hailfall.

76N

Fournier, d'Albe E.M. (1976)

"Climatic Zones Favorable for Cloud Seeding with Hygroscopic Nuclei"

2nd WMO Scientific Conference on Weather Modification: 3-6

The author discusses cloud seeding with hygroscopic nuclei (salt particles of mass between 10^{-9} and 5.10^{-9}g.). Criteria for suitability of climatic zones for cloud seeding with hygroscopic nuclei are given.

760

Fukuta, N., Plooster, M.N., Armstrong, J.A., and Butz, J. (1976)

"Operational Organic Ice Nuclei Smoke Generators"

2nd WMO Scientific Conference on Weather Modification: 511-519

Environmental hazards of Ag I seeding are discussed. These hazards are presumably absent with organic ice nucleants, such as 1,5-dihydroxy-naphthalene, methaldehyde, and phloroglucinol, which are biodegradable. Consideration is given to the cost and operation of organic smoke generators. Silver iodide and 1,5-dihydroxynaphthalene ice nucleation is compared, the primary difference being a shorter fallout time for the Ag I.

76P

Gray, W.M., W.M. Frank, M.L. Corrin, and C.A. Stokes (1976)

"Weather Modification by Carbon Dust Absorption of Solar Energy"

2nd WMO Scientific Conference on Weather Modification: 425-432

About 60-80% of the incoming solar energy reaches the surface of the earth. The authors discuss the possibility of increasing the amount of energy absorbed by the atmosphere by up to 15% by releasing clouds of hydrocarbon particles (~0.1 μm in size) in the troposphere. It is hypothesized that this procedure would enhance rainfall, reduce hurricane intensity, alter extratropical cyclones, inhibit frost, and accelerate snow melting. Simulation studies are recommended.

76Q

Haas, Eugene J., Changnon, Stanley A., Davis, Ray J., Farhar, Barbara, and Swanson, Earl (1976)

"Impact Assessment of Future Hail Suppression Technologies in the U.S."

2nd WMO Scientific Conference on Weather Modification: 585-592

This paper considers such matters as:

(1) the technology of hail suppression - e.g. seeding procedures.

(2) Effects of hail suppression on other meteorological phenomena, such as rainfall and surface winds

(3) Legal and political considerations.

(4) Whether or not improved hail suppression technology, when it exists, will be adopted and

(5) economic benefits of successful hail suppression.

It is noted that improved hail suppression technologies are not particularly attractive economically for the nation as a whole, but have considerable merit on a local scale.

76R

Held, G. and Carte, A.E. (1976)

"Variability of Hailstones"

2nd WMO Scientific Conference on Weather Modification: 241-248

The article is a study of various characteristics of hailstorms and hailstones. Data collected over long periods of time are studied, and characteristics that are relatively stable from year to year. Among these stable characteristics are mean duration of point hailfalls and the distribution of the largest and commonest hailstones. Some other characteristics studied are extremely variable.

76S

Henz, John F., Mulvey, Gerald J., and Grant, Lewis O. (1976)

"The Potential for Annual Precipitation Augmentation of the High Plains and Foothills Areas"

2nd WMO Scientific Conference on Weather Modification: 63-69

The authors discussed the conditions, both seasonal and meteorological, under which weather modification procedures have the most effect in eastern Colorado. Hourly precipitation data from a 16 year period, was analyzed. The conclusions are that Spring and Summer are the most favorable seasons for weather modification procedures, that up-slope cloud systems are best for winter operations, and that storm systems offer the best opportunities in Spring and Summer.

76T

Hindman, Edward E., Tag, Paul M., Silverman, Bernard A., and Hobbs, Peter V. (1976)

"Calculations of the Effects on Rainfall Caused by Cloud Condensation Nuclei from a Paper Mill"

2nd WMO Scientific Conference on Weather Modification: 21-24

The effect of plumes from paper mills in western Washington state were discussed. A numerical model was used to simulate the dynamic, thermodynamic, and microphysical processes involved in the formation of rain from cumulus clouds. This model was used to calculate the effects on rainfall of CCN emitted from paper mills.

It was concluded that CCN from papermills cannot account for rain showers observed downwind of the mills in the Pacific Northwest.

76U

Howell, Wallace E. (1976)

"On the Use of Homoclines for Estimating Environmental Effects of Precipitation Management"

2nd WMO Scientific Conference on Weather Modification: 577-584

One method of assessing the overall effect of weather modification is to select an area (other than the target area) which is generally similar to the target area but has the type of climate one would like to induce in the target area. An area of this sort is called a homocline. Such a homocline is the best way to study long term effects of modified weather. To study short term effects, it is better to use historical data from the target area itself, collected at a time in which the type of weather one wishes to induce occurred naturally.

76V

Kachurin, L.G., and Kartsivadze, A.I. (1976)

"On Hail Suppression Possibilities at the Modern Stage of the Atmospheric Processes Modification Means and Techniques Development"

2nd WMO Scientific Conference on Weather Modification: 223-228

In this paper, various seeding schemes for hail suppression are discussed. Idealized plans are compared with real-life circumstances, in which perfect conditions do not prevail. The problems of sufficient rocket launching rates are discussed.

76W

Kahan, A.M., Todd, C.J., Howell, W.E., and Silverman, B.A. (1976)

"Project Hiplex - Plans, Progress, and Approach"

2nd WMO Scientific Conference on Weather Modification: 27-34

This paper was a summary of the goals and methods of project Hiplex, a weather modification study carried out by the Bureau of Reclamation. Emphasis was placed on developing of computer models for the forecasting of experimental events and for developing seeding hypotheses. Data in field experiments was gathered by radar and a sparse network of rain gauges.

76X

Kiss, Alexandre-Charles (1976)

"Legal Aspects of Weather Modification"

2nd WMO Scientific Conference on Weather Modification: 549-555

Legal problems associated with weather modification are discussed. Topics considered include whether the operator or the person who ordered the operation is responsible for damages arising from a weather modification operation and establishing that the weather modification procedure was indeed the cause of the damage. The particular problem of damage in one nation resulting from weather modification procedures in another is given special consideration. Cases in which this has occurred are reported.

76Y

Klein, D.A. and Giangiordano, R.A. (1976)

"Evaluation of Potential Impacts of Silver Iodide Nucleating Agents on Aerobic and Anaerobic Aquatic Microbiological Processes"

2nd WMO Scientific Conference on Weather Modification: 569-575

Experimental Design: The study was conducted to determine the effects of weather modification agents on Hyphomicrobium (a type of bacteria) growth initiation, morphology, and methanogenesis. Hyphomicrobium was used in all studies. The cultures (basic mineral salts medium) were kept at 9-33° C. Silver ions additions were made in distilled water. Bacterial growth was measured by a spectoric 20. For methanogenesis studies, the cultures were maintained in mud or sewage sludge and gassed with helium to maintain anaerobic conditions. Analyses for methane production were carried out by using a aerograph 1200 flame ionization gas chromatigraph.

Conclusions: Large doses of silver may be needed to cause decreases in methanogenesis, an important anaerobic process. The postulation that silver has a greater effect on anaerabic than aerobic processes may require reconsideration.

76Z

Knight, Charles, and Dye, James A. (1976)

"Seeding 'Cold Cumulus' with Ice Nuclei to Enhance Precipitation"

2nd WMO Scientific Conference on Weather Modification: 77-83

The author conjectured that certain cumulus seeding projects have failed because of the natural multiplication of ice particles within the seeded clouds. It was suggested that the seeding of cumuli to enhance precipitation should be confined to clouds where drops > 25μm do not reach a critical concentration below -8° C.

76AD

Nelson, Loren D. (1976)

"Numerical Simulation of Natural and Seeded Hail-Bearing Clouds"

2nd WMO Scientific Conference on Weather Modification: 371-380

The microphysical cold-cumulus model developed by the Bureau of Reclamation is studied in detail. The consequences of this model for hail suppression are considered. Possible decreases in rainfall as a result of hail suppression are discussed.

76AE

Nelson, Stephan P. (1976)

"Characteristics of Multicell and Supercell Hailstorms in Oklahoma"

2nd WMO Scientific Conference on Weather Modification: 335-340

Hail data was collected over a period of years in Central Oklahoma by means of a network of volunteers who observe and report hail fall. This data was compared to the classification of the storm as multicell or supercell. It was established at the 5% level of significance that there is a difference in the maximum hailstone size and maximum swath width of multicell and supercell storms. Severe weather (other than hail) is most often associated with supercell storms.

76AF

Nickerson, E.C., Chappell, C.F., and Magaziner, E.L. (1976)

"Effect of Seeding on the Dynamics of Cold Orographic Clouds"

2nd WMO Scientific Conference on Weather Modification: 123-130

Studies of the behavior of cold orographic clouds with and without ice microphysical processes were carried out, combining the mesoscale dynamic model of Nickerson and Magaziner (1976) with the cold cloud microphysical model of Cappell and Smith (1976). The consequences of in-cloud ice-concentration and vertical motion fields for weather modification experiments are discussed.

In this paper, both the importance of understanding airflow patterns within storms and the current lack of knowledge are discussed. Models for airflow patterns and their consequences from the viewpoint of weather modification are given. It is conjectured, based on these models, that the most effective way to seed cumulus clouds is to seed the rising tops at the -13 to -17°C level.

76AA

List, Roland (1976)

"Objectives and Status of the WMO Precipitation Enhancement Project"

2nd WMO Scientific Conference on Weather Modification: 445-456

The goals of the WMO Precipitation Enhancement Project are stated and discussed. The major goals are, in part:

(1) To plan and carry out scientifically controlled precipitation enhancement experiments,
(2) To demonstrate at a statistically significant level that any increase in precipitation is not a chance event, but associated with the seeding,
(3) To increase understanding of cloud physics,
(4) To obtain well-documented evidence that may lead to optimization of the effects of seeding and
(5) To disseminate procedures on how to set up, execute, and evaluate weather modification experiments.

76AB

Medvedev, G.A. (1976)

"Experimental Investigation of Cb evolution in Conformity to the Seeding Problem"

2nd WMO Scientific Conference on Weather Modification: 321-328

This paper discusses the estimation of outer wind influence on radar echo axis of individual Cb. Estimation of certain meteorological parameters is considered, and their application to hail suppression is mentioned.

76AC

Mossop, S.C. (1976)

"Failure of Cloud-Seeding Projects caused by National Ice Crystal 'Multiplication'"

2nd WMO Scientific Conference on Weather Modification: 71-76

76AG

Núñez, J.M., Saluzzi, M.E., and Peinado, O.A. (1976)

"Differences in Behavior of Large Convective Clouds Leeward of the Andes Mountains at 34° South"

2nd WMO Scientific Conference on Weather Modification: 312-320

The paper is a consideration of ways to distinguish whether or not a given cloud will be a hail producer. Factors considered include maximum reflectivity value of a radar echo, radio echo thickness, air temperature at top level, and radio echo maximum altitude. Although differences between the parameters associated with hail and non-hail clouds appear, the differences are not conclusive and do not allow an excluding typification. The correlation between hail/no hail and cloud parameters is high, so a probabilistic prediction is possible.

76AH

Parungo, F.P., Patten, B.T. and Pueschel, R.F. (1976)

"Ag I Ice Nuclei: Their Properties and Effectiveness"

2nd WMO Scientific Conference on Weather Modification: 505-512

The environmental effects of releasing large quantities of Ag I into the atmosphere are unknown. This paper considers the possibility of effective seeding using less Ag I. It is found that microscopic particles of S_iO_2, encapsulated with Ag I, are suitable for sublimation nucleation, while economizing the consumption of Ag I. The mixing of Ag I with such hygroscopic salts as K I, Na I, and NH_4 I substantially decreases the ice-nucleation abilities of Ag I.

76AI

Reid, John D., Grant, Lewis O., Pielke, Roger A., and Mahrer, Yetzaq (1976)

"Observations and Numerical Modeling of Seeding Agent Delivery From Ground Based Generators to Orographic Cloud Base"

2nd WMO Scientific Conference on Weather Modification: 521-527

This paper summarizes the results of field studies and numerical models of delivery of seeding agent to cloud base, conducted to increase understanding of the first stage of modification process. These studies confirm that the seeding agent can reach the cloud base in effective concentration. The presence of a orographic cloud inhibiting radiatively the formation of strong surface based inversions appears to be important in permitting the transport out of lowest layers.

76AJ

Reynolds, David W. and Matthews, David A. (1976)

"Real Time Satellite Support for the High Plains Co-operative Experiment"

2nd WMO Scientific Conference on Weather Modification: 497-504

The papers purpose is to show how satellite imagery may be used to support a summertime weather modification project. The High Plains Cooperative Project was chosen for study. Satellite data was used to provide information about the type of convective triggering mechanisms and in describing the wide area convective, mesoscale, and synoptic interactions. Satellite imagery was used to provide real-time information regarding extent of clouds, rate of development, movement, and mesocale organization.

76AK

Reynolds, David W., Vonder Haar, Thomas H., and Grant, Lewis O. (1976)

"Overview of Satellite Support to Weather Modification"

2nd WMO Scientific Conference on Weather Modification: 483-489

This paper consists of a brief discussion of the history of the use of satellites in the gathering of meteorological data, with emphasis on the application of satellites to weather modification procedures, and a look at possible supporting capabilities that are available from satellites. These possible support capabilities include:

(1) monitoring and growth to estimate the rate of cloud growth,
(2) satellite vertical temperature soundings,
(3) cloud-top temperature measurements in the IR to estimate cloud intensity and
(4) determining the relative distribution of ice and liquid water in clouds.

76AL

Sauvalle, E. (1976)

"Operational Fog Dispersal Systems at Orly and Charles de Gaulle Airports Using the Turboclair Process"

2nd WMO Scientific Conference on Weather Modification: 397-404

The Turboclair process is a fog dispersal process in which hot gases are released above a runway to raise the temperature and vaporize the suspended water droplets. The paper is a summary of results achieved by using this method at Paris airports.

76AM

Sartor, J.D. and Cannon, T.W. (1976)

"Simulation of the Growth of Hail from Observed Cloud and Environmental Characteristics"

2nd WMO Scientific Conference on Weather Modification: 363-370

A mathematically tractable model of convection patterns within storm clouds is developed, in which circulation is formulated analytically and kinematically from the type of convective cells that develop normally in a dynamic two-dimensional model of convection with randomly distributed thermal sources. The model predicts hailstone size, and predicted hailstone size is compared with observed hailstone size from several storms.

76AN

Scheetz, Vincent R. and Grant, Lewis O. (1976)

"Satellite Observations of Seedable Upslope Cloud Systems"

2nd WMO Scientific Conference on Weather Modification: 491-496

The purpose of this study was to investigate the potential for augmenting precipitation by studying upslope cloud systems as viewed by satellite. NOAA polar orbiter IR data were used to determine the extent of the cloud and cloud top temperature for twelve days with upslope clouds. Reviewing of precipitation for the case study days supported the contention that warmer clouds are inefficient producers of precipitation.

76AO

Scott, Bryan C. and Hobbs, Peter V. (1976)

"A Theoretical Study of Some Effects of Artificial Seeding on Mixed Phase Cumulus Clouds"

2nd WMO Scientific Conference on Weather Modification: 117-122

A 1-D time dependent cumulus model involving detailed microphysics was used to investigate effects of cloud seeding on maritime and continental cumulus clouds. Effects of seeding at cloud top and seeding in columnar growth region are examined in both maritime and continental clouds.

76AP

Smith, E.J. and D.E. Shaw (1976)

"Some Aspects of the Assessment of a Site for a Cloud-Seeding Experiment"

2nd WMO Scientific Conference on Weather Modification: 165-172

Criteria for choosing a site for a cloud seeding experiment are given, based on duration of experiments, concentration of rain gauges, and availability of meteorological covariates. Simulated experiments were carried out, based on historical data.

The chance of detecting a change in rainfall increases with the magnitude of the change, experimental duration, and with the number of gauges. It decreases with the length of the randomized seeding period.

76AQ

Tag, Paul M. (1976)

"Clearing Fog by Seeding with Charged Water Drops: a Numerical Study"

2nd WMO Scientific Conference on Weather Modification: 405-412

The potential uses of seeding with charged water drops are discussed. This method of seeding is compared with hygroscopic seeding. It is shown that an electric field improves visibility by droplet fallout from spectral widening. There is no consideration given to the feasibility of electrical seeding, only its effectiveness.

76AR

Vardiman, L., Moore, J.A., and Elliot, R.D. (1976)

"Generalized Seedability Criteria for Winter Orographic Clouds"

The authors conducted a post-hoc analysis of seven randomized winter orographic seeding projects and attempted to develop generalized seedability criteria that could be applied for varying meteorological and topographic conditions. Relationships between meteorological and topographical parameters are sought.

76AS

Vento, Dominico and Morgan, Griffith (1976)

"Statistical Evaluation of Energy Imported to Hail by Wind in Europe and United States"

2nd WMO Scientific Conference on Weather Modification: 281-286

Data gathered by high density networks throughout Western Europe and the United States were considered. Damage potential of hail and its enhancement by wind were discussed. The kinetic energy of hailfall due to wind was found to be of a highly variable nature.

76AT

Weinstein, Alan I. and Kunksel, Bruce (1976)

"Fog Dispersal - An Operational Weather Modification Technology Today"

2nd WMO Scientific Conference on Weather Modification: 381-388

This paper is a discussion of the capabilities and limitations of various types of fog dispersal techniques. Differing fog types - and the effectiveness of dispersal techniques on each type - are discussed. Thermal fog dispersal, hygroscopic material seeding, and helicopter downwash mixing are discussed, along with unproven methods such as electrostatic methods and compressed air for supercooled fog dispersal.

1977
77A

Atlas, David, (1977)

"The Paradox of Hail Suppression"

Science, 195, pp. 139-145

The author discusses reports of successful hail suppression and also reports of negative effects. He also discusses why it is so difficult to arrive at conclusive and consistent results.

Topics covered include:

1. Hail Suppression Concepts.
2. Some Hail Suppression Results.
3. Some Physical Reasons for Increased Hail.
4. Some Implications for the Future of Hail Suppression.
5. A First Approach to Physical Stratification

In his summary he notes that there is a tendency to attribute both positive and negative results of hail suppression programs to differences in seeding methodology and rate. However, he notes that both positive and negative results have been found in a variety of seeding methods.

Furthermore, he observes that without rational physical stratification of the data, a randomized statistical experiment may be statistically inconclusive because of the balancing positive and negative effect and without such stratification, we will probably be unable to improve our seeding methodology.

Finally, to enhance the chances of success of a statistical experiment, Atlas proposes a scheme of stratification between the conditions leading to increased or decreased hail. Also he notes that the strength of a statistical experiment would be enhanced and its duration reduced by the use of a strong covariate; dynamic hail potential is one of the most likely candidates.

77B

Neyman, Jerzy (1977)

"A Statistician's View on Weather Modification Technology"

Statistical Laboratory, University of California, Berkeley, California

It is concluded that cloud seeding is not at present a reliable means of relieving drought conditions. However, evidence is given that cloud seeding does affect precipitation, sometimes positively and others negatively, for great distances from the seeding site.

Problems associated with the design and analysis of weather modification experiments are discussed, such as unconsious bias on the part of the experimenter. Examples of inconsistences on the part of official sources are given.

A mechanism which could account for losses of precipitation following summer cumulus seeding is proposed.

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AUTHOR INDEX

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